DATELINE: LOS ALAMOS

UNDER THE VOLCANO

3-D IMAGE OF MOLTEN ROCK PROMOTES NEW THINKING ON AN ANCIENT CALDERA

A three-year study of seismic waves traveling through the heart of an ancient volcano has provided researchers at Los Alamos with the first comprehensive three-dimensional image of the caldera and new and important information about the volcano's plumbing system. The purpose of the study was to assess volcanic hazards, determine geothermal resource potential, and better understand how large rhyolitic calderas form and evolve.

↑ The crater of an ancient volcano — the Valles Caldera — lies west of Los Alamos.

The study reveals a large low-velocity zone 8 miles in diameter, centered at a depth of 8 miles below the caldera. This zone contains at least 10 percent molten rock, or magma. The researchers can't rule out the possibility that the zone of magma, or magma chamber, is the remnant of volcanism from more than a million years ago. However, they favor the idea that it represents the emplacement of a relatively new pulse of magma into Earth's crust.

A deeper zone of low velocity, found at depths of about 23 miles, is interpreted to reflect the source rocks — possibly molten — of the magmas that formed the shallower magma chamber.

Researchers Lee Steck of Los Alamos and William Lutter of the University of Wisconsin led a team of researchers who recorded travel times of seismic waves from distant earthquakes traveling through the Valles Caldera in Northern New Mexico. The seismic waves analyzed by the researchers are essentially sound waves that travel faster in stiffer material and slow down in more pliable material, such as magma.

Using tomography, a method similar to the computer-aided tomography, or CAT scan, of medical imaging, geophysicists produced a 3-D computer model that shows seismic waves slow down by as much as 35 percent in specific locations beneath the Valles Caldera.

The Valles Caldera, located about 70 miles north of Albuquerque, formed during two explosive episodes that occurred 1.6 million years

ago and 1.2 million years ago when more than 90 cubic miles of rock erupted. The caldera's most recent volcanic activity ended 50,000 years ago. The 14-mile-wide Valles Caldera is one of the most well-known resurgent calderas in the United States. Scientists have been studying this region since the 1920s to learn about the fundamental processes of magmatism, hydrothermal systems, and ore deposition.

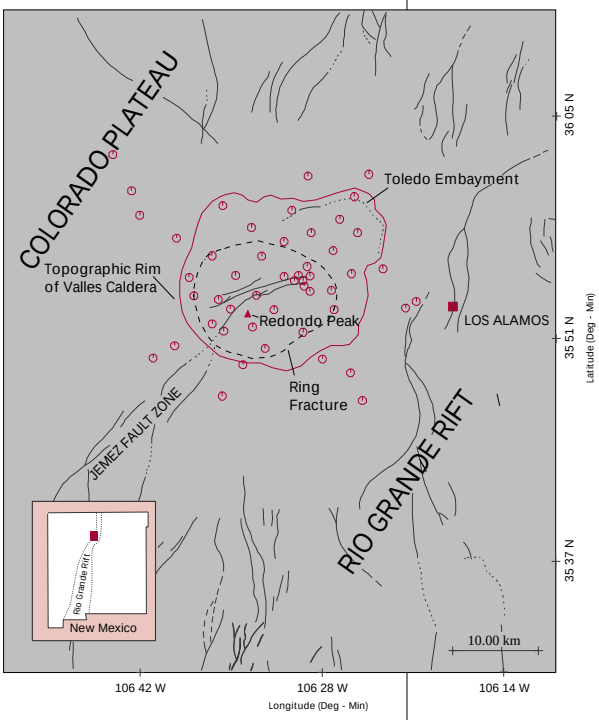
Resurgent calderas form after a huge volcanic eruption, when the roof of the magma chamber collapses into the space voided by gas-rich magma. The collapsed crater then fills partially with volcanic ash and pumice.

The research team placed 50 seismic monitoring stations around and within the Valles Caldera, which lies just west of Los Alamos in the Jemez Mountains. This monitoring network produced a detailed picture of the velocity structure down to depths of 24 miles below the surface. Data were gathered from 216 distant earthquakes, most of which occurred during the 1993 and 1994 Jemez Tomography Experiment. Data gathered from a 1987 experiment by Los Alamos researcher Peter Roberts were also included in the study.

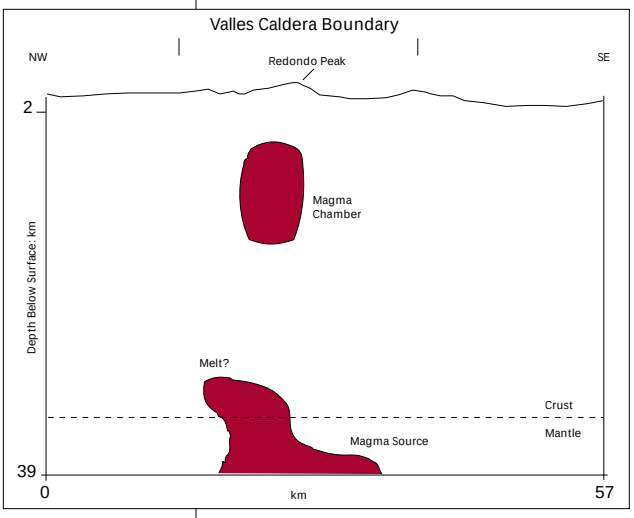
Researchers analyzed 4,872 seismic waves. Seismic waves from faraway earthquakes approach the instruments nearly vertically, while seismic waves from earthquakes that are closer come in at a more horizontal angle. The researchers need both near and far earthquakes for a wide variety of angles to produce the 3-D model.

When the Valles Caldera collapsed nearly 1.2 million years ago, researchers believe it occurred in a more stair-stepped than piston-like manner, resulting in deeper areas filled with more volcanic ash and sediments. Steck and Lutter's research confirms that theory.

The research team found several areas of shallow low-velocity zones slightly deeper than a mile from the caldera floor that were slower than surrounding areas by about 10 to 17 percent. The



Location of the Valles Caldera on the western flank of the Rio Grande Rift in Northern New Mexico. Seismic stations are indicated by small red circles.



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Researchers' interpretation of the magma chamber centered at a depth of 8 miles below the caldera, and the deeper zone of magma found at depths of about 23 miles.

research team believes these represent the greater accumulation of pyroclastic deposits in areas of deeper collapse on one side of the caldera.

There are three possible interpretations of the 3-D velocity image. The first is that the original million-year-old magma is still cooling underneath the caldera. The second is that the original magma chamber was rejuvenated or in contact with the mantle to periodically receive more melt. The third interpretation is that the observed low-velocity zones represent a completely new pulse of magma.

Steck and Lutter agree that the original magma chamber may still exist and could retain up to 10 percent of its melt products, but certainly not more. However, they say the calculations supporting this premise require numerous simplifying assumptions and may not be realistic. From these and other arguments, the researchers favor the third interpretation.

Taken together, the low-velocity regions at depths of 8 and 23 miles are believed to show the relationship between magma emplacement at the base of the crust, and its subsequent rise to the middle crust to form a magma chamber. The research method can only image an area larger than about 2 miles. If there are conduits or connections between the magma chamber and the deeper low-velocity region, and they are smaller than 2 miles in diameter, the technology cannot image them.

The research project is part of the Jemez Tomography Experiment, a cooperative and interdisciplinary research program involving scientists from Los Alamos, the University of Wisconsin, San Diego State University, the University of Texas at Dallas and El Paso, Purdue University, and the U.S. Geological Survey.

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